The International Journal Of Engineering And Science (IJES)
|| Volume || 3 || Issue || 5 || Pages || 19-24 || 2014 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Embedded energy of on farm losses and energy analysis for maize production in Nigeria

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ABSTRACT

Food losses and wastages occur at different points in the food supply chains such as farm, processing, storage, transportation, food services and household. On farm losses are associated with the losses of embedded energy. Thus, embedded energy of on farm maize losses and general energy flow pattern was investigated. Primary and secondary data were used. Primary data was collected through multistage stratified random sampling of 40 maize growers while secondary data was obtained from yearly in-situ collection of agricultural data by agricultural agency in Nigeria. Therefore the analyzed and discussed input energy- output energy values were averages of data collected over the years. Total energy input and output were respectively quantified as 9502.17 and 33510.58 MJha^{-1}. The input energy estimated was classified as industrial energy (84.38%), biological energy (15.62%), direct energy (31.14%) and indirect energy (68.86%). Energy efficiency, energy productivity, specific energy, net energy and agrochemical energy ratio were 3.53, 0.19 kgMJ^{-1}, 5.28 MJkg^{-1}, 24008.41MJha^{-1} and 60.1% respectively. The total embedded energy in the lost maize for the period of study was 6816.13MJ. The high loss of maize on Nigeria farm was an indicator for increased in embedded energy lost from 214.03-1995.53MJ. Year 2012 had the highest share of embedded energy loss (29.28%) followed by year 2011(28.46%), while lowest share of (3.14%) was estimated for the year 2000.

KEYWORDS- *Embedded energy, input-output energy, farm losses, maize production*

Date of Submission: 05 October 2013 Date of Publication: 20 May 2014

I. INTRODUCTION

Food losses and wastages occur at different points in the food supply chains such as farm, processing, storage, transportation, food services and household. (Jones, 2006). UNEP,(2009) estimated that more than half of the food produced in the world is either wasted, loss or discarded due to inefficiency in the human managed food chain. Accurate estimations of the magnitude of losses and waste are still lacking in developing countries (Samuel et al., 2011). FAO (2011) respectively estimated yearly quantitative food losses and waste in sub-Saharan African countries as 21, 54, 31, and 66% for cereals, tubers, oilseeds and fruit crops. On farm maize losses need proper estimation due to its position as a major economy grains in Nigeria (FAO, 2013, Phillip, 2001). On farm losses are associated with the losses of embedded energy since increase in crop yield is mainly due to increase in commercial energy inputs in addition to improved crop varieties (Mohammadshirazi et al., 2012). Energy in agriculture is important in terms of crop production and agro processing for value adding (Banaeian and Zangeneh, 2011). Modern agriculture is heavily dependent on high input of fossil energy, which is consumed as ‘‘direct energy’’ (fuel and electricity used on the farm) and as ‘‘indirect energy’’ (energy expended beyond the farm for the manufacture of fertilizers, plant protection agents, machines, etc.). Both direct and indirect forms of energy are required for agricultural productions in terms of its development and growth. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems for agricultural sustainability (Lorzadeh et al., 2012).

Reported literature on energy expenditure in crop cultivation include; plantain production in Nigeria (Jekayinfal et al., 2012), Field crops in Turkey (Canakci et al., 2005) maize cultivation (Banaeian and Zanggeneh, 2011, Lorzadeh et al., 2011) and tangerine production in Iran (Mohammadshirazi et al., 2012), but there is no information on embedded energy of on farm losses and energy analysis of maize production, a major crop in Nigeria. Therefore the objective of the present study was to estimate the amount of energy embedded on farm maize losses, analyze energy flow and examine energy use efficiency in maize agro ecosystem.

II. MATERIAL AND METHODS

This study utilized both primary and secondary data. Primary data was collected from the surveyed of maize growers in the agricultural zones of Oyo state categorized by the state agricultural development programme. The state is located in the south-west of Nigeria between latitude $7^0 3^|$ and $9^0 12^|$ north of the equator and longitudes $2^0 47^|$ and $4^0 23^|$ east of the meridian with average temperature of 27^OC. Primary data (input and output energy sources and quantity per unit area) was collected with the help of questionnaire. The sampling technique employed was multistage stratified random sampling technique. The first stage involved purposive selection of four agricultural zones (Ibadan/Ibarapa, Ogbomosho, Oyo and Saki). The second stage involved purposive selection of two blocks from each zone making a total of 8 blocks. The third stage involved simple random selection of 5 maize growers each from the eight blocks. 40 maize growers were then interviewed between January and July 2013. The data was transformed to energy term by appropriate energy equivalent factors (Table1). The secondary data was obtained from statistical resource of Oyo Sate agricultural development programme. In the maize production agro ecosystem of this district, input energy sources included human labour, machinery, diesel fuel, fertilizer, chemicals and seeds; while output energy sources was maize grain yield. The standard equations 1-7 were the tools used in the estimations of embedded energy on-farm maize losses and energy flows during the production of maize. The quantity of on-farm losses was estimated based on 6% losses on Nigeria farm (FAOSTAT, 2012). Using equation 1

$$On\ farm\ maize\ losses = 0.06\ x\ Total\ production \qquad (1)$$

$$\text{Embedded energy of on farm losses} = energy\ equivalent\ x\ quantity\ wasted \qquad (2)$$

$$Energy\ productivity = maize\ output/energy\ input \qquad (3)$$

$$Specific\ energy = energy\ input//maize\ output \qquad (4)$$

$$Net\ energy = energy\ output - energy\ input \qquad (5)$$

$$Energy\ efficiency = energy\ output/\ energy\ input \qquad (6)$$

$$Agrochemical\ energy\ ratio\ (\%) = \frac{input\ from\ chemical\ input\ \ (MJ/ha)}{total\ input\ energy\ (MJ/ha)} \qquad (7)$$

Table 1: Energy equivalent of input and output values in agricultural production.

Input quantity per unit area h	Energy equivalent (MJ/unit)	Quantity per unit area	Total energy equivalent (MJ)
A. Input			
Human labor (h)		534.15	1046.93
Land preparation	1.96	52.15	102.21
Cultural practices	1.96	468	917.28
Harvesting	1.96	14	27.44
Machinery (h)		6.28	393.76
Land preparation	62.7	3.6	225.72
Cultural practices	62.7	0.93	58.31
Transportation	62.7	1.75	109.73
Diesel fuel (L)	47.8	40	1912
Fertilizers (kg)		200	5482.74
Nitrogen	64.4	66.7	4295.48
Phosphorus	11.1	66.7	740.37
Potassium	6.7	66.7	446.89
Chemicals		2.42	229.24
Pesticides	101.2	0.4	40.48
Herbicides	92	2	184
Fungicides	238	0.02	4.76
Seeds (kg)	17.5	25	437.5
Total energy input (MJ)			9502.17
B.Output			
Maize yied (kg)	17.5	1800	31500
Lost maize	17.5	114.89	2010.58
Total energy output(MJ)			33510.58

III. RESULTS AND DISCUSSION

3.1 Input-output energy use

The average yield of maize was 1800kg $ha^{-1}$with energy equivalent of 31500MJ. Table 2 shows the inputs used and output in maize production system in the studied area. The total energy requirement for producing maize crops was 9502.17MJha^{-1}.The main sources of total energy used in the production processes "Fig. 1" were 58, 20, 11,5and4% for fertilizer, diesel fuel, human labor, seeds and machinery respectively. Among the different energy sources, fertilizer was the highest energy consumer for the studied crops. The average use of fertilizer was 200kg ha^{-1} in the maize production. The result obtained in this study agrees with the findings of Lorzadeh et al. (2011) and Mobtaker et al. (2010) for maize production.

3.2 Energy indicator in maize production

The energy indicator of maize production agro ecosystem, energy use efficiencies, energy production net energy and agrochemical energy ratio of maize production are presented in Table 3. Energy use efficiency and specific energy in this agriculture system was determined to be 3.53 and 5.28MJkg^{-1} respectively. In a similar study by canakci et al.(2005) in Anatalya region of Turkey, the yield of maize production was calculated as 6600 kgha^{-1} with energy ratio of 3.8 and lower specific energy of 3.88 MJkg^{-1}. Low amount of energy use efficiency is an indication of inefficiency use of energy in maize production system (Banaeian and Zangeneh, 2011). The average energy productivity of maize production system was 0.19kgMJ^{-1}. This means that 0.60kg of maize was obtained per unit of energy or in the other word, in maize production system 5.26MJ energy used for producing one kg maize grain. Calculation of energy productivity ratio is well documented in the Literature. Jekayinfa et al. (2012) reported 0.79 for plantain production in Nigeria, while Lorzadeh et al. (2011) reported 0.13 for maize production in Iran. The net energy in this study for maize production was 24008.4 MJha^{-1}. Also agrochemical energy ratio of maize production agro ecosystem was also calculated as 60.11 percent which illustrate more energy consumption per fertilizer and chemical inputs in production (Khan et al., 2009). The shares of forms of energy "Fig. 2" are classified as Industrial (84.33%), biological (15.62%) or direct (31.14%) and indirect energy (68.86%). The higher ratio of industrial over biological energy and indirect over direct energy is in agreement with findings of Mohammedshirazi et al. (2012) for maize production. The results reveal that consumption of chemical fertilizers, diesel fuels and labour as the highest energy inputs for maize production in the zone.

3.3 Embedded energy

The embedded energy in maize from year 2000-2012 is shown in Table 4. The total embedded energy in lost maize for the period of study was 6816.13MJ. The high loss of maize on Nigeria farm accounted for increased in embedded energy lost from 214.03-1995.53MJ. Year 2012 had the highest embedded energy lost (29.28%) followed by year 2011 (28.46%). The embedded energy lost estimated for year 2010, 2009, 2008, 2007, 2006 and 2005 were 3.46, 3.48, 3.71, 3.77, 3.56 and 4.34 % of the total energy lost respectively. The embedded energy lost estimated for year 2004, 2003, 2002 and 2001 were 4.53, 4.27, 4.41 and 3.58% of total lost energy respectively. Year 2000 have the lowest embedded energy lost with the share of 3.14%. The embedded energy obtained in this study was higher than what was reported by Cu'ellar (2010) for USA grains. It can be inferred that the embedded energy loss in this analysis represents a significant amount of lost energy through wasted maize. The intensity of energy discarded in wasted maize is more than energy intensity in certain agricultural operation such as manual land preparation and wet milling maize reported Jekayinfa et al. (2012) and Akinoso et al (2013) respectively. Consequently, the energy embedded in wasted maize represents a substantial target for decreasing on farm losses in Nigeria maize production.

Table 2: Input and output and their energy equivalent in Nigeria maize production.

Input quantity per unit area h	Energy equivalent (MJ/unit)	Quantity per unit area	Total energy equivalent (MJ)
A. Input			
Human labor (h)		534.15	1046.93
Land preparation	1.96	52.15	102.21
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Potassium	6.7	66.7	446.89
Chemicals		2.42	229.24
Pesticides	101.2	0.4	40.48
Herbicides	92	2	184
Fungicides	238	0.02	4.76
Seeds (kg)	17.5	25	437.5
Total energy input (MJ)			9502.17
B.Output			
Maize yied (kg)	17.5	1800	31500
Lost maize	17.5	114.89	2010.58
Total energy output(MJ)			33510.58

Table3: Indicator of energy use in maize production system

Indicators	Unit	Quantity
energy use efficiency		3.53
specific energy	$MJkg^{-1}$	5.28
energy productivity	$kgMJ^{-1}$	0.19
agrochemical energy ratio	%	60.11
net energy	$MJha^{-1}$	24008.41
industrial energy	$MJha^{-1}$	8017.74
biological energy	$MJha^{-1}$	1484.43
direct energy	$MJha^{-1}$	2958.93
indirect energy	$MJha^{-1}$	6543.24

Table4: Farm yield, losses and embedded energy for maize production

Production year	On-farm losses(MT)	Energy in yield(MJ)	Embedded energy in lost maize(MJ)
2000	12.23	3566.5	214.3
2001	13.93	4064.2	243.78
2002	17.19	5013.05	300.83
2003	16.64	4854.5	291.20
2004	17.65	5147.28	308.88
2005	16.91	4933.08	295.938
2006	13.86	4042.5	242.55
2007	14.69	4284	257.08
2008	14.45	4213.83	252.88
2009	13.57	3956.4	237.48
2010	13.49	3934.88	236.08
2011	110.85	32330.38	1939.88
2012	114.03	33258.75	1995.53

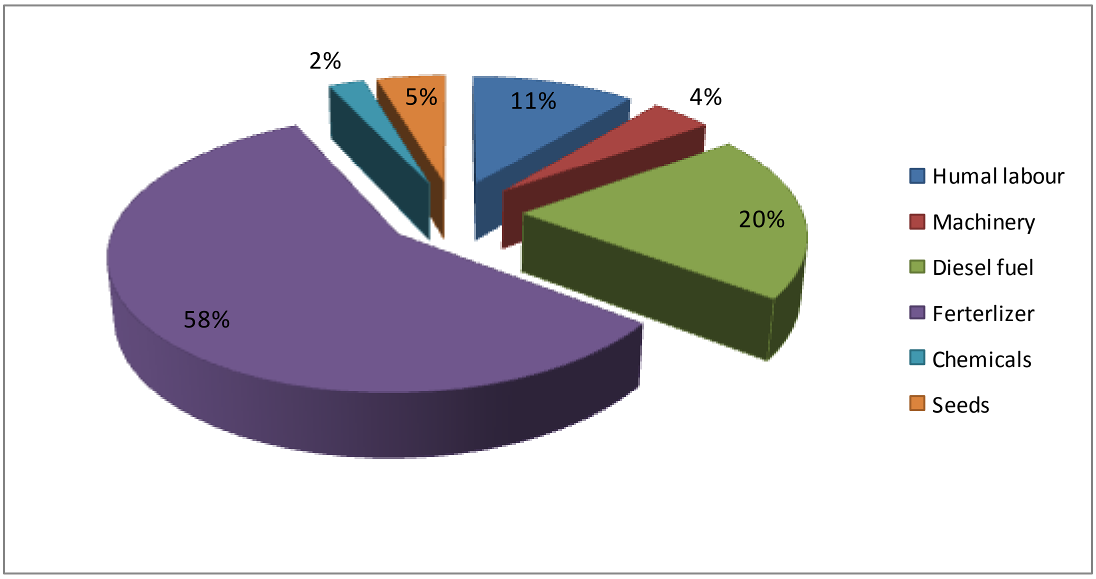

Figure1: Distribution of inputs energy in maize production

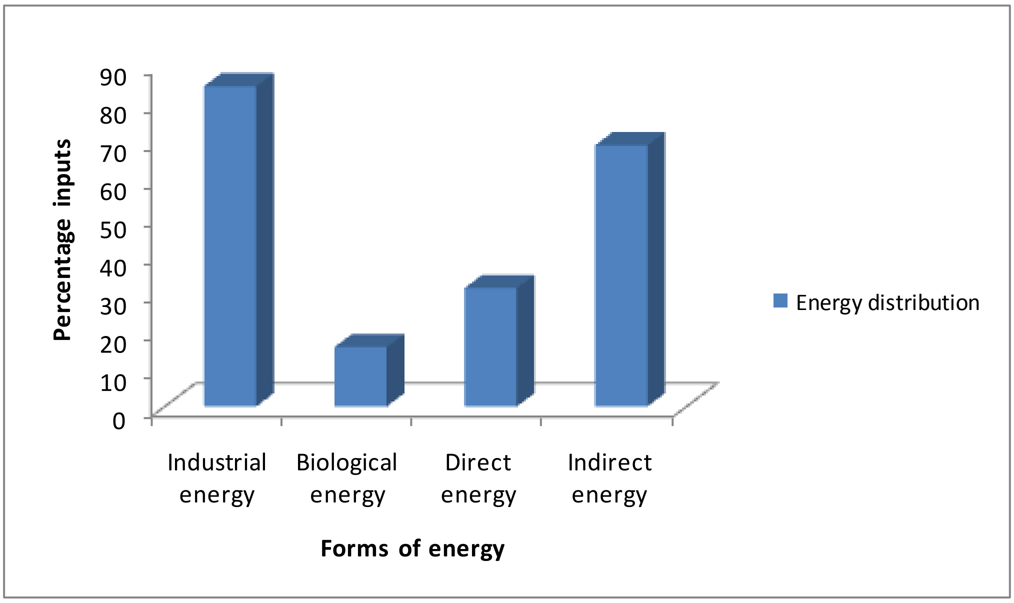

Figure2: Share of energy forms

CONCLUSIONS

[1]. Based on the present study, the following conclusions are drawn;

[2]. The total energy consumption in maize production was 9502.17 $MJha^{-1}$ and the output energy was 33510.58 $MJha^{-1}$.The energy input estimated were industrial energy (84.38%), biological energy (15.62%), direct energy (31.14%) and indirect energy (68.86%)

[3]. Energy efficiency, energy productivity, specific energy, net energy and agrochemical energy ratio were 3.53, 0.19 $kgMJ^{-1}$, 5.28 $MJkg^{-1}$, 24008.41$MJha^{-1}$ and 60.1% respectively.

[4]. The total embedded energy in the lost maize for the period of study was 6816.13MJ. The high loss of maize on Nigeria farm was an indicator for increased in embedded energy lost from 214.03-1995.53MJ. Year 2012 had the highest share of embedded energy loss (29.28%) followed by year 2011(28.46%), while lowest share of (3.14%) was estimated for the year 2000.

[5]. The energy embedded in wasted maize represents a substantial target for decreasing on farm losses in Nigeria maize production.

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